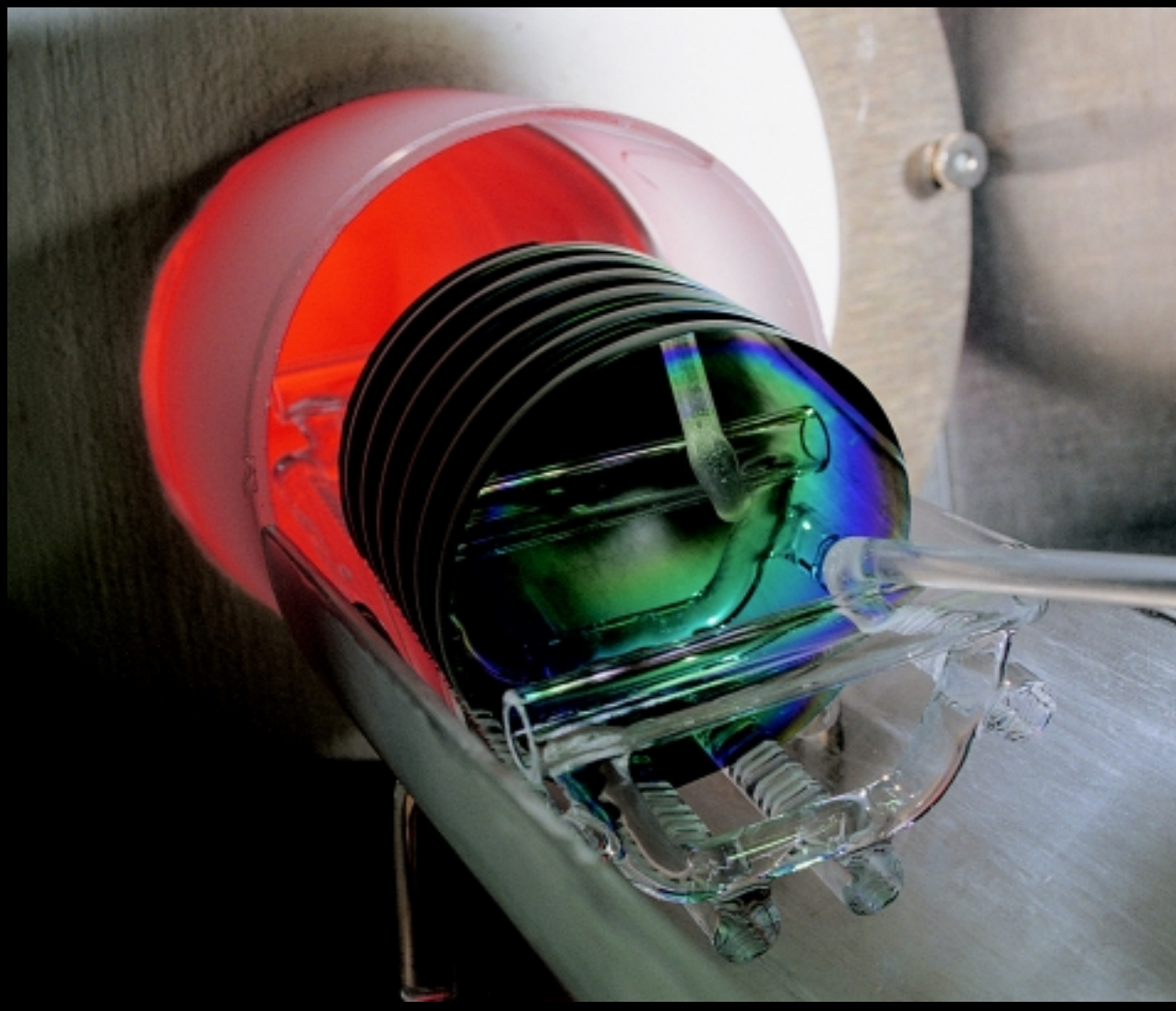
Advancing technology

to become the best.



Institute for Physical Research and Technology

annual report 1999

Iowa State University

IPRT Centers

The Institute for Physical Research and Technology is a network of research and technology-transfer centers and industrial-outreach programs at Iowa State University.

Airworthiness Assurance Center of Excellence
Identifies and provides solutions for national aircraft-safety problems

Ames Laboratory of the U.S. Department of Energy
Conducts fundamental research in energy, materials and chemical sciences

Center for Advanced Technology Development
Assists in technology transfer and industrial problem-solving

Center for Nondestructive Evaluation
Develops noninvasive methods and instruments for assessing the integrity of structures and materials

Center for Physical and Computational Mathematics
Researches high-performance computing via cluster-computing and parallel-computing strategies

Center for Rare Earths and Magnetics
Provides information on rare earths and studies magnetic material properties

Center for Sustainable Environmental Technologies
Develops and demonstrates renewable energy and chemical technologies, and environmental technologies related to fossil fuels

Materials Preparation Center
Prepares specialized high-purity metal compounds for research and engineering uses

Microanalytical Instrumentation Center
Develops innovative, small-scale analytical and bioanalytical instruments for emerging analyses

Microelectronics Research Center
Develops and characterizes advanced semiconductor materials devices and processing technology

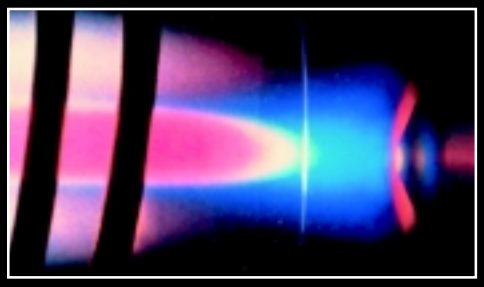
Virtual Reality Applications Center
Applies virtual reality technology to the challenges of science and engineering

Industrial Outreach Programs

Iowa Companies Assistance Program
Helps Iowa companies solve materials-related questions and problems

Iowa Demonstration Laboratory for Nondestructive Evaluation Applications
Assists Iowa businesses with nondestructive evaluation techniques and training

Iowa Industrial Incentive Program
Provides funding to help Iowa businesses use ISU's research and technical capabilities



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On the front cover: Silicon wafers are loaded into the Microelectronics Research Center's silicon-diffusion furnace. The wafers will be used in the fabrication of microelectronic devices, including chemical sensors and photovoltaic devices.

On the back cover: Spatial mechanisms are synthesized in the Virtual Reality Application Center's C2 virtual environment.

Inside front cover: A brilliant emission from hot argon inductively coupled plasma. Elements are converted into atomic ions in the ICP, reducing the time Ames Laboratory researchers need to measure radionuclides with long half-lives.

The Iowa State University theme for 1999-2000, “Advancing technology to become the best,” is an ideal one for the Institute for Physical Research and Technology. In part, it is simply a rephrasing of our mission statement — to move forward the engineering and physical science discoveries of ISU.

IPRT accomplishes this goal by developing new technologies, transferring novel discoveries to industry or start-up companies and identifying the right set of capabilities at ISU to solve manufacturing problems.

But although at IPRT we want to become the best at what we do, we know that the test of our success is really whether we are helping those we serve to become their best. This report highlights some of the IPRT activities that advanced technology in ways that helped Iowa companies in the past year as they worked to become the best.

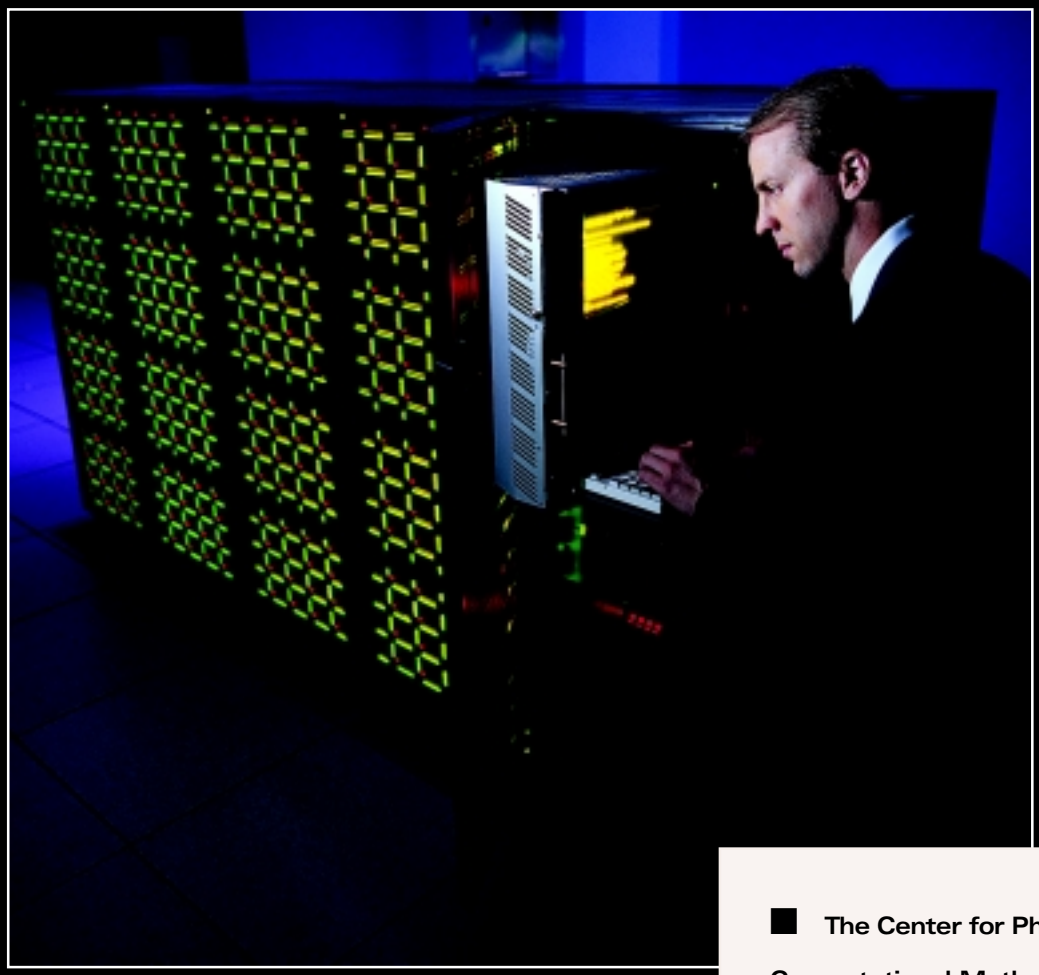
If as you read this report you find ways we might serve you, give IPRT a call. Let’s become the best, together.

Sincerely,

Tom Barton
IPRT Director

Advancing technology

to become the best.



■ The Center for Physical and Computational Mathematics has acquired a 256-node Intel Paragon system, one of the world's fastest computers when new in 1995 and still a powerful supercomputer.

It is used by scientists like Dave Turner to study photonics, structural configurations of biological molecules and semiconductor surfaces.

Aircraft Safety

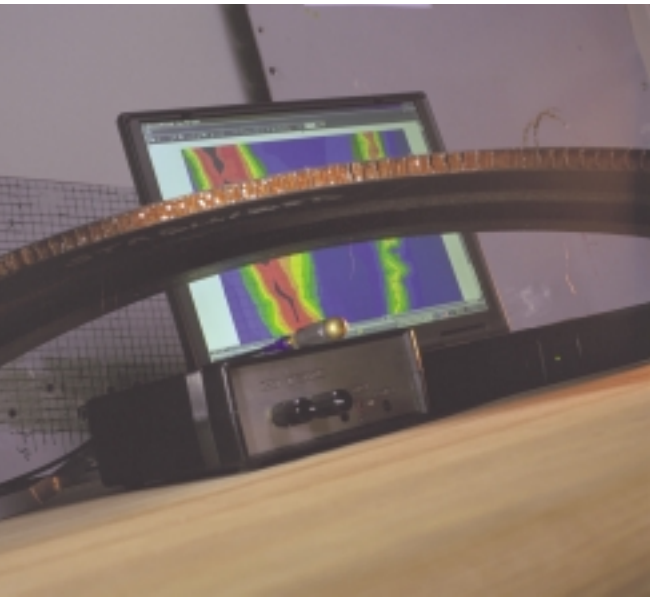
Improving inspection techniques through sound and imaging

A coin is hardly what comes to mind when considering high-tech tools, but airlines depend on a coin-like device to tap on parts and listen for "dead zones." IPRT scientists have discovered a way to improve this inspection technique by converting sound data into an image that tells information about the stiffness and bonds within the part.

"The airline maintenance hangar is a noisy place, and hearing-based tap tests can be subjective and inaccurate," said David Hsu, a scientist at the Center for Nondestructive Evaluation. "Furthermore, the inspectors do not have a good way to assess the size, shape and severity of a defect or damage. Our instrumented tap-test system has imaging capability and can provide information about the stiffness of the part while keeping the technique simple and inexpensive."

"Our instrumented tap-test system has imaging capability and can provide information about the stiffness of the part while keeping the technique simple and inexpensive."—David Hsu, scientist, CNDE

The instrumented tapper consists of an accelerometer with a brass tip, small electronic circuits, a notebook computer, a grid and software. To begin inspection, the grid is placed over the structure and the part is tapped in the grid pattern. Just as the ear can hear the tap, the accelerometer "hears" the sound and sends an electronic signal. The electronic circuits then modify the signal to measure the contact time, which is short when a part is structurally sound and longer when an area of the part is damaged.



An image depicting a tapped area's structural soundness is displayed behind the honeycomb paper core of an aircraft part.

The tapper then translates this information into digital data, which is fed directly into the serial port of the notebook computer. The computer displays the impact duration as an image instantly; then, with the click of a button, it converts the data into an image of the stiffness, or structural soundness, of the tapped region. This makes it easier for technicians to determine the amount of damage and to monitor the damage over time.

A mechanized version of the tapper is now being developed. Hsu said the project, now in its second year, will require less than three years of Federal Aviation Administration funding to complete.

The tapper has been tested at Northwest Airlines in Minneapolis, Minn., American Airlines in Tulsa, Okla., TWA in Kansas City, Kan., and the Iowa Army National Guard and Iowa Air National Guard. Several airlines have expressed an interest in the technology.

Biomass Energy Conversion

Creating new uses for agricultural products

When Henry Ford built auto parts out of plant material in 1941, he was acknowledged as a visionary for agriculture. Ford would be pleased to know that nearly 60 years later, IPRT researchers are growing similar technologies at the Biomass Energy CONversion Facility, known as BECON, in Nevada, Iowa.

IPRT scientists are taking common agricultural byproducts, called biomass, including corn stalks, switchgrass, woodchips and livestock waste, and converting them into economically and environmentally viable fuels and chemicals. Their efforts include:

Using thermal gasification to produce gas with a high energy content. Robert Brown has developed a biomass gasifier that converts solid biomass into flammable gas mixtures. The gasifier produces gases with energy content high enough to fuel gas turbines and fuel cells or for use in chemical synthesis.

Converting biomass to methane. In an oxygen-free environment, anaerobic bacteria convert biomass into organic acids, which are further converted to methane and carbon dioxide. Shihwu Sung assisted in the design of an innovative high-efficiency anaerobic digester called the Temperature-phased Anaerobic Digestion system. The system will convert corn stover and swine waste into methane, a renewable energy resource.

Extracting high-value chemicals from plants. Robert Brown and Tony Pometto are extracting industrial chemicals from corn stover using a process that incorporates both thermal and biological techniques. Biomass is heated in an oxygen-free environment where it produces a high-sugar liquid. The liquid is fermented and converted to lactic acid and other valuable industrial chemicals. In another project, Walter Trahanovsky is working to derive from biomass, particularly cellulose, chemicals that could be used in the synthesis of complex organic compounds.

The fuels and chemicals resulting from IPRT research at BECON can be used not only to power equipment but in a variety of industrial and household products, including plastics, adhesives, paints, inks, dyes, detergents, surfactants and solvents.

"Finding new uses for agricultural products through value-added research conducted at BECON can help improve the farm economy and provide sustained rural economic development," said Norm Olson, program manager of the BECON facility. "It makes sense that Iowa, with its significant agricultural industries, leads the way in developing and expanding the market for value-added, biomass-based fuels and chemicals."

The fuels and chemicals resulting from IPRT research at BECON can be used not only to power equipment but in a variety of industrial and household products, including plastics, adhesives, paints, inks, dyes, detergents, surfactants and solvents.

Cluster Computing

Developing supercomputer speed at an economical cost

When IBM officials arrived at Ames Laboratory in April, they could hardly wait to see how "Cluster" was doing. Like any doting parent, the folks from IBM were anxious to see where their child was living, how it had grown and how it was performing in its new home.

Cluster is the name given by Ames Laboratory's Scalable Computing Lab staff to a network of 15 dual-processor, IBM Power3 RS/6000 workstations. This incredible infant lives in the fourth-floor "penthouse" of Wilhelm Hall and is the latest and greatest cluster computing network at Ames Lab and Iowa State University. Its birth was made possible by IBM's Shared University Research Grant to ISU — $665,000 in top-of-the-line equipment.

"Professor Gordon's team has built a world-class learning laboratory using this new technology (cluster computing) to solve real-world scientific problems."— Jeff VerHeul, vice president of Server and Workstation Development, IBM Server Group

Cluster computing involves networking groups of high-performance workstations to create clusters that operate at supercomputer speed and at an economical cost.

"The SUR grant is highly competitive," says Mark Gordon, director of Ames Lab's Applied Mathematics and Computational Sciences Program and an ISU distinguished professor of chemistry. "The fact that we received it says that Ames Lab's and ISU's combined expertise is very attractive to IBM and that they see great promise in our collaborative efforts." Jeff VerHeul, vice president of Server and Workstation Development, IBM Server Group, said the SUR grant allows IBM, Ames Lab and ISU to work closely to explore the performance of clustered systems. "All three organizations will benefit from the discovery and shared learning currently underway," said VerHeul, who received a bachelor's degree in computer engineering from ISU in 1980. "Professor Gordon's team has built a world-class learning laboratory using this new technology to solve real-world scientific problems."

Already making its family proud, Cluster is running calculations on groups of atoms and molecules and helping researchers determine the best ways to communicate between computers in a cluster. A technology child prodigy of sorts, Cluster uses its outstanding computing power for applications in theoretical chemistry and physics, such as running quantum chemistry code and modeling new materials with specific magnetic and high-temperature properties.

Materials Development

Discovering the second-hardest bulk substance after diamond

Ames Laboratory researchers believe they've found a material that will join the ranks of diamond and cubic boron-nitride as ultrahard materials used in grinding and machining applications.

The scientists discovered that introducing a small amount of silicon and other additives into an alloy of aluminum-magnesium-boron creates the second-hardest bulk substance after diamond.

Although the research is not yet complete, the scientists have measured the material's hardness on several different instruments. Its hardness was measured at 46 gigapascals (the equivalent of 6.7 million pounds per square inch), slightly higher than cubic boron-nitride's hardness of 45 GPa (6.5 million psi). Diamond's hardness is estimated at between 70 and 100 GPa (10.2-14.5 million psi).

The discovery could mean big cost savings for manufacturers who use these types of materials in abrasives and cutting tools — especially for the auto industry, which relies heavily on cubic boron-nitride for grinding and machining hardened steel.

Cubic boron-nitride costs between $2,000 and $5,000 per pound, while the aluminum-magnesium-boron compound costs about $700 per pound. Diamond costs around $2,000 per pound but can't be used with steel because it reacts when brought into contact with iron-based materials at high temperatures.

Researcher Bruce Cook discovered the hardness of aluminum-magnesium-boron while researching its thermoelectric properties in 1992. He was unable to cut samples of the material with the high-speed, precision diamond saws on hand. Although the material had been around for awhile, its mechanical properties hadn't been fully investigated.

Because of the complex structure of the material's unit cell, or fundamental building block, Cook thought he could improve the hardness by substituting other elements, such as silicon. "We thought we could change the bonding environment if we added the silicon to the structure, and it worked. It made the material harder," he said.

Cook and colleague Alan Russell are hoping to investigate other additives that could make the material even harder. "This was the first additive we tried and it resulted in a significant increase in hardness. There may be other variations that could further increase the hardness of this material," Cook said.

Through the Center for Advanced Technology Development, Cook and his colleagues received one-year funding from the U.S. Department of Commerce to study the material and possible additives. The researchers are looking for additional funding to continue exploring the material's preparation and properties.

The discovery could mean big cost savings for manufacturers who use these types of materials in abrasives and cutting tools — especially for the auto industry, which relies heavily on cubic boron-nitride for grinding and machining hardened steel.

Materials Processing

Contributing to cancer research and treatment

Cancer research and metallurgy are not commonly mentioned in the same sentence. In fact, they seem to be two fields that would never intersect.

However, IPRT scientists at the Materials Preparation Center have been working with a San Diego-based company, Ablation Technologies, which is developing a technique for treating prostate cancer. MPC has been preparing samples of palladium-cobalt alloy critical to the research effort.

The procedure being developed is called "thermal ablation." The method involves the implantation of many small alloy rods into the prostate and heating them by applying a high-frequency magnetic field. The prostate is heated to temperatures as high as 120 to 160 degrees F, essentially destroying the diseased tissues. The procedure is less invasive than traditional surgery and has many potential advantages over existing techniques for treating localized prostate disease. Preliminary results from international clinical trials are generating enormous interest within the medical community.

The Materials Preparation Center's John Wheelock pulls a sample of newly minted palladium-cobalt alloy from the furnace. The specialized material is a critical component in a novel technique being developed to treat prostate cancer.

While the concept seems simple enough, the difficulty arises in fine-tuning the ratio of palladium to cobalt to manufacture material of the proper target temperature. To do this, MPC director Larry Jones explained, researchers take advantage of a materials property called the Curie temperature, the point at which the material becomes nonmagnetic. Once the magnetic field heats the rods to their Curie temperature, they stop heating and automatically regulate at precisely that level without requiring any external connections. Using this principle, researchers have developed a simple, self-regulating heat source.

To this point, MPC has been supplying Ablation Technologies with ingots of the alloys for their research. However, the company has begun development work with a commercial supplier. "We don't want to be in the game of where we're providing materials that are being used to manufacture products," said Jones. "Once the R&D's over, we like to transfer the technology."

Currently, Ablation Technologies has two international clinical trials underway and has approval for a U.S. trial beginning in early 2000. Jones and the MPC researchers are hoping the treatment ultimately receives full FDA approval as an effective prostate cancer treatment.

"Esoteric science is good, pushing back the frontiers and everything is super," Jones said. "But when you can actually help develop a material that's used for the benefit of mankind, I think that's a warmer, fuzzier feeling."

Nondestructive Evaluation

Solving problems close to home

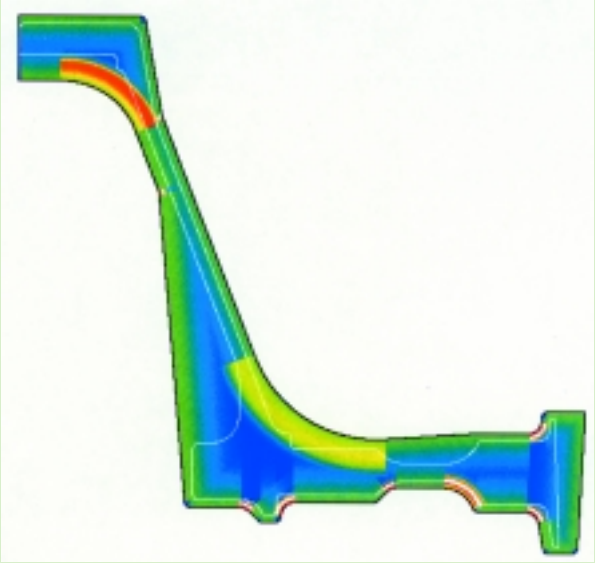
Fusing various types of expertise and identifying strengths is an important part of advancing any area of research. IPRT scientists are doing both to advance nondestructive evaluation.

IPRT's Center for Nondestructive Evaluation is one of five institutions in the Alliance for Research and Development of Advanced Manufactured Assembly. The organization studies and responds to various generic needs related to welding and coatings. Institutions were invited to participate based on their expertise. "Of course, CNDE came to mind when we started talking about experts in nondestructive evaluation," said Robert Carnes, research associate at the University of Texas, Austin, and co-developer of the alliance.

CNDE is currently developing fatigue and inspection criteria for steel catenary (chain) risers, which connect pipelines on the ocean floor to offshore oil and gas production facilities. Center scientists are assessing the reliability of ultrasonics for inspecting the welds.

But CNDE scientists are also joining with colleagues to solve problems closer to home. With researchers at Northwestern University, Joe Gray and his team are looking at issues related to castings — parts produced by pouring molten metal or other material into a mold. Many Iowa companies produce castings, and because one part can replace many, casting can usually save money while adding strength. However, castings are susceptible to defects such as porosity. Since an engineering methodology has not been established to assess how these imperfections affect the strength and life of a part, castings are often overlooked for safety-critical components in automotive or aerospace applications.

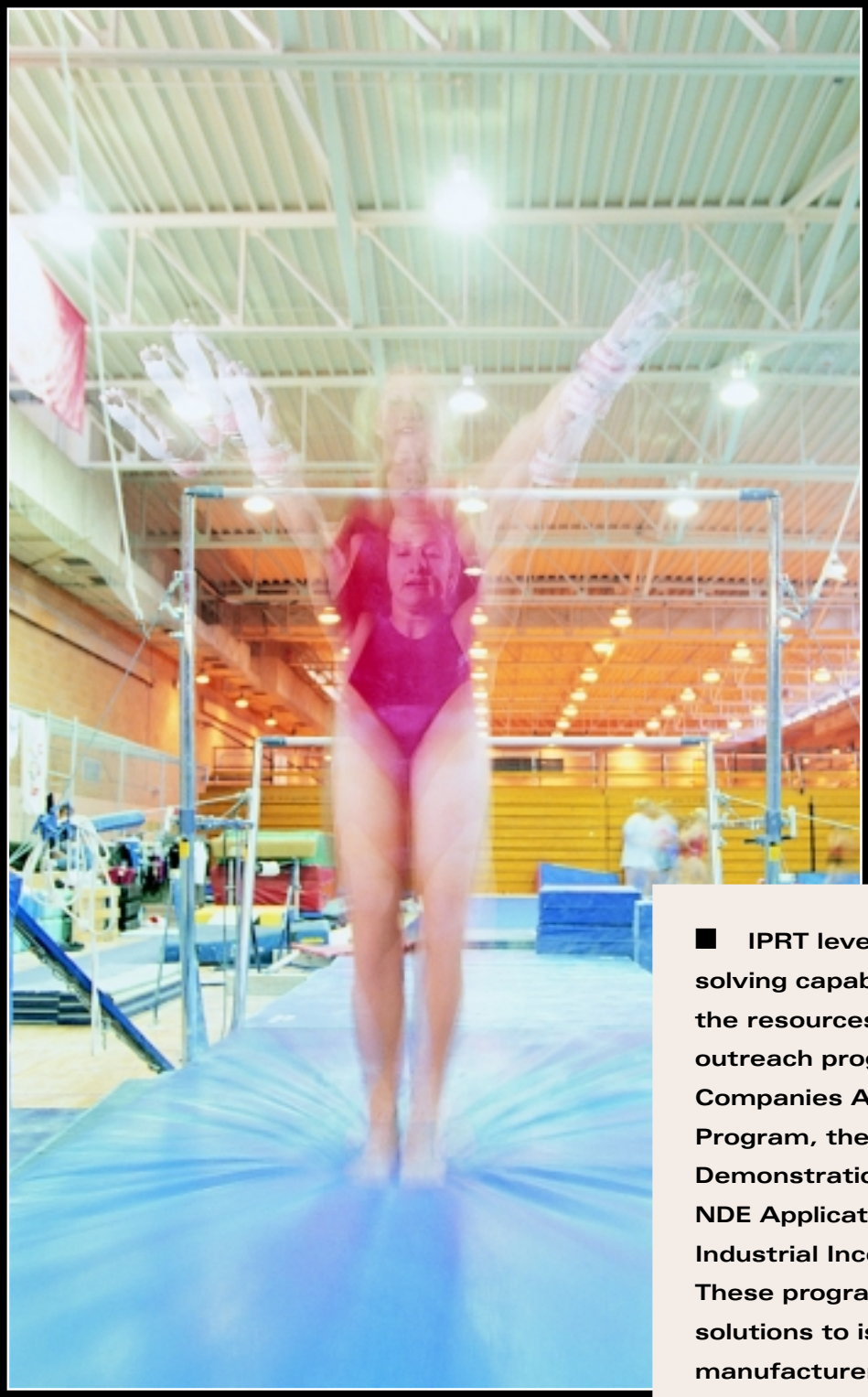
Gray and his team are developing tools to evaluate the competing and complex issues related to the use of cast parts. Although the research is in its early stages, "we have developed modeling tools that allow the effects of defects to be calculated, the inspectability of the part to be determined and optimized, and the effect of casting parameters on the likelihood to produce porosity to be predicted," said Gray. "These tools allow the determination of how new materials will behave without the need for extensive and expensive testing of a large number of parts."



■ CNDE scientists are collaborating with AlliedSignal, General Electric and Pratt & Whitney to develop improved techniques to detect flaws in rotating components of aircraft engines, thereby avoiding uncontained engine failures. This image, which has arisen from the work of the Engine Titanium Consortium sponsored by the Federal Aviation Administration, shows a color-coded map indicating the effectiveness of a particular inspection in various regions of a part. Red denotes the greatest sensitivity and dark blue the lowest.

Advancing technology

through outreach to industry.



■ IPRT leverages its problem-solving capabilities through the resources of three outreach programs: the Iowa Companies Assistance Program, the Iowa Demonstration Laboratory for NDE Applications and the Iowa Industrial Incentive Program. These programs help provide solutions to issues Iowa manufacturers face, including product improvement, quality control, reliability and new product development challenges.

Accessing Expertise to Advance Products

"We are evaluating new products to see if they take us where we want to go . . . I'm glad to be back on campus working with professors on real-world problems our company faces."— Joe Hadar, director of Research and Development, Hadar Manufacturing

When officials at Hadar Manufacturing in Humboldt, Iowa, needed experts to put their gymnastics mats to the test, ISU's Center for Advanced Technology Development forged a link for them.

Through the Iowa Industrial Incentive Program, CATD enabled Hadar to access the expertise of Tim Derrick and Scott McLean, ISU professors of health and human performance. Derrick and McLean used equipment in the biomechanics laboratory of the department of health and human performance at ISU to research the impact characteristics of selected Hadar mats.

The mats were subjected to a battery of tests: impact, force platform and friction. All three are influenced by the properties of the mat and can play a role in ensuring athlete safety.

In the impact test, weights were dropped onto mats from different heights using a device for testing athletic shoes. The deformation on the mats and the resulting return of energy to the weights after contact were measured.

Human subjects participated in force tests resembling real-life situations. In these tests, individuals with varying physical builds jumped from different heights onto the mats. A platform under the mats measured the level of force subjects experienced upon landing. To measure friction, weighted shoe soles were attached to a digital force gauge and pulled across the mats.

This initial baseline research will aid Hadar Manufacturing in developing mats that better suit different athletic activities. Harder mats with greater energy return may perform best for jumping and tumbling, though softer mats may reduce levels of friction and injuries when making sudden stops.

Joe Hadar, Hadar's Research and Development director and an ISU alumnus, supports taking advantage of ISU's expertise for advancing products: "We're improving our understanding of the way cushioning works to help athletes perform. Now that we're more familiar with the terrain, we are evaluating new products to see if they take us where we want to go—if they give us the performance characteristics we expect," he said. "I'm glad to be back on campus working with professors on real-world problems our company faces."

For more information on the Iowa Industrial Incentive Program, call (515) 294-4644, e-mail *laurenzo@iastate.edu* or visit the Web site at *http://www.catd.iastate.edu.*

The State of Iowa Industrial Incentive Program provided $368,358 in funding for 30 cost-sharing product research and development projects with Iowa-based companies.

Providing Companies with

- **Evaluation**
- **Information**
- **Education**

Forensic science is more than just piecing together clues from crime scenes. Paul Berge, an industrial specialist with the Iowa Companies Assistance Program, often wears the hat of a forensic metallurgist when providing Iowa manufacturers the information and education they need to improve their products.

Metallurgists at ICAP are available to address a range of materials and manufacturing issues Iowa companies encounter. Berge's investigative skills proved valuable when Vermeer Manufacturing Company, a global producer of industrial construction and agricultural equipment based in Pella, Iowa, needed clues about blade cracks in its tree chippers. Hairline cracks in blades supplied by an outside vendor held potential for product performance troubles.

Investigation of a chipper blade allowed Berge to identify the initial crack and how it progressed from a once-small hairline crack to a dramatically deeper one. Berge concluded that a force perpendicular to the crack split the blade and that the answer lay in the original production process.

After polishing a cross-section of a blade to examine the steel, Berge found that decarburization was the culprit. Carbon had apparently been pulled from the metal in the production process, thereby weakening it. Varying levels of hardness in regions of the blade could also have caused stresses that ultimately led to cracking. Following these conclusions, Berge identified courses of action that Vermeer could use to minimize or eliminate the risk of further cracks.

"Our job at ICAP is to provide companies with the evaluation, information and education they need to improve their products. We've provided Iowa manufacturers with such services as problem identification, testing and locating information they need to make product selection decisions," Berge said.

Through ICAP, skilled engineers like Berge, program director Thomas Lograsso and faculty from ISU's College of Engineering chip in to provide companies up to 40 hours of no-cost technical assistance. With information gained from working with ICAP, companies may become better equipped to resolve product concerns with third-party manufacturers or to improve their own production processes.

For more information on ICAP, call 1-800-884-8548, e-mail *icap@iastate.edu* or visit the Web site at *www.iprt.iastate.edu/icap.html.*

ICAP scientists identified causes of blade cracks in Vermeer Manufacturing's tree chippers.

Sharing the Resources of

- **Time**
- **Technology**
- **Expertise**

ISU engineers provided product testing for Frog Legs' wheelchair swivel caster assembly.

Who better to test the longevity of a wheelchair part than a mechanical engineer who spends his days in one? A network of ISU experts, with support from the Iowa Industrial Incentive Program, brought John Roberts, an engineer with the Center for Industrial Research and Service, together with a young Vinton, Iowa, company called Frog Legs, Inc.

Frog Legs, a manufacturer of wheelchair suspension systems, solicited help from ISU to test their product's performance. The Center for Advanced Technology Development's Iowa Industrial Incentive Program paired Roberts with the company to test swivel caster assemblies, the joints that connect small wheels at the front of wheelchairs.

Roberts and other wheelchair passengers know that effective shock absorption is a must because it prolongs the life of chairs, reduces the risk of spasms for passengers who are paralyzed and improves mobility when traveling over uneven surfaces. Frog Legs' swivel caster assembly uses a polyurethane cylinder that cushions the chair and passenger from jolts.

At ISU's Town Engineering Structures Laboratory, Roberts and a group of engineering students put the swivel caster assembly through "fatigue testing," designed to simulate a lifetime of use in several hours. The caster assembly was subjected to 10 series of 10,000 cycles of compression and examined for signs of damage and weakness. After every series, the assembly was taken apart and the cylinder was placed in a tensile/compression-testing machine where numerical data on its ability to manage different loads was gathered.

"This kind of testing provides multiple benefits: to verify that the part is functioning as it should, to find out if the product's performance has improved because of design changes and to determine if alternative uses are possible," Roberts said.

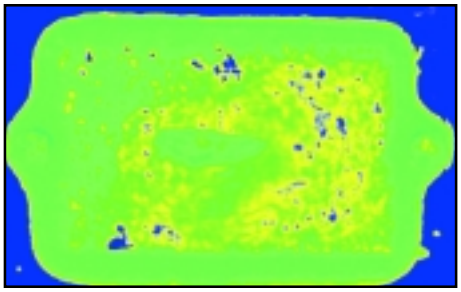
CATD'S Iowa IIP provided partial funding for the research. To establish the cost-sharing agreement, ISU and Frog Legs partnered to fund the design and testing. Frog Legs' engineer Dave Carr, also an ISU alumnus, can now take his knowledge of tensile and compression testing and conduct additional in-house research at the company's Vinton facility.

"Many small companies don't have the time, technology or expertise to perform their own product research," said Kim Bentley of CATD. "The Iowa IIP helps Iowa by enabling companies to stay in-state where they receive this support."

For more information on the Iowa IIP, call (515) 294-4644, e-mail *laurenzo@iastate.edu* or visit the Web site at *http://www.catd.iastate.edu.*

Offering Manufacturers

- **Problem Identification**
- **Techniques**
- **Training**



IDL scientists used a beam of ultrasound to examine this laminated nickel transducer in one of Bluewave's ultrasonic cleaning tanks.

A shortage of scrubbing bubbles brought Bluewave Ultrasonics Inc. of Davenport, Iowa, to the Iowa Demonstration Laboratory for Nondestructive Evaluation Applications.

Bluewave uses ultrasonic technology in the high-performance industrial cleaning equipment it manufactures. High-frequency sound waves produce "bubbles," and their popping creates scrubbing activity. Laminated nickel transducers convert electrical energy into bubble-making vibrations.

The Iowa Demonstration Laboratory came to Bluewave's aid after the company reported inconsistencies in the nickel in its transducers. At the same time, the flux normally used to bond transducers to the bottom of the cleaning tanks was discontinued. Bluewave selected a different flux but was concerned the two factors could have led to reduced product performance.

IDL responded to Bluewave's concerns with ultrasonic waves of its own. Staff used an inspection technique that sends a beam of ultrasound into the brazed (bonded) interface and listens for reflected energy from unbonded and porous areas. Results indicated that the bond quality was not degraded by the change in flux.

Electrical conductivity and magnetic properties of the nickel were evaluated using eddy-current and other magnetic measurement techniques. The conductivity and magnetic characteristics of the troublesome batch were found to be significantly different from those of a problem-free batch of nickel.

"After identifying the new batch of nickel as the probable cause, we informed Bluewave of inspection methods and equipment they could use to evaluate materials in-house," said Brian Larson, IDL program director.

IDL provides up to 40 hours of no-cost technical assistance to Iowa companies. NDE methods, namely X-ray, ultrasound, eddy-current, magnetic-particle and liquid-penetrant inspection, can be used to test the integrity of materials and components and to control processes. IDL acquaints manufacturers with NDE techniques and performs studies to develop and optimize NDE procedures. Since much of the equipment is portable, IDL staff can literally take the technology right to its industrial clients.

In addition to helping with performance troubles, IDL may have found a niche for Bluewave's products. "Cleaning is a very important step in some NDE techniques — Bluewave's products could get a lot of attention from the NDE community," Larson said.

Bob Larson, Bluewave's operations manager, echoed the benefits of this new relationship. "IDL provided quick answers to our problems, which could have been critical and costly without their help. IDL's value to a company like ours can't be measured."

For more information on IDL, call (515) 294-8152, e-mail *idl@cnde.iastate.edu* or visit the Web site at *http://www.cnde.iastate.edu/idl/idl.html.*

■ The Virtual Reality Applications Center's C2, a 12-by-12-by-9 ft. projection-based virtual reality environment, provides researchers new insight into engineering problems, as demonstrated by this display of fluid velocity vectors.

Our Focus on Education

1999 Ames Lab/ISU Regional Science Bowl: What the buzz is all about

Skill, not size, proved to be the winning element in the Ames Laboratory/ISU 1999 Science Bowl. With a team composed of only three students, the Ankeny High School team cruised to a first-place finish. Defeating Pleasant Valley High School, Ankeny is the only school in the Lab's history to win with a three-person team — most are four or five students strong. West Des Moines Valley High School, the 1998 National Science Bowl champions, took third.

Over 200 students from 40 Iowa schools were drilled on their science and math knowledge during the daylong January event. About 70 volunteers from Ames Laboratory and ISU served as moderators, judges, scorekeepers and timekeepers.

Ankeny progressed to DOE's National Science Bowl in Chevy Chase, Md., with 52 other regional winners. In 1999, more than 9,000 students from 1,800 schools took part in Science Bowl competitions.

Science Bound: Meeting the needs of students and the workforce

Science Bound, now in its 10th year, was initiated to help meet the needs of the 20th-century workforce. This collaborative effort with Des Moines public schools involves students, parents, teachers, ISU scientists and Des Moines business/scientist mentors with the goal of increasing the number of ethnic minority students pursuing technical careers.

Field trips, Saturday visits to ISU and regular meetings with teachers are part of the 8th-12th grade program. For the second year, Science Bound students also participated in the weeklong residential Early Outreach Program at ISU.

More than 180 students are enrolled in the 1999-2000 program. Those who successfully complete Science Bound and pursue a technical degree receive a full-tuition scholarship at ISU.

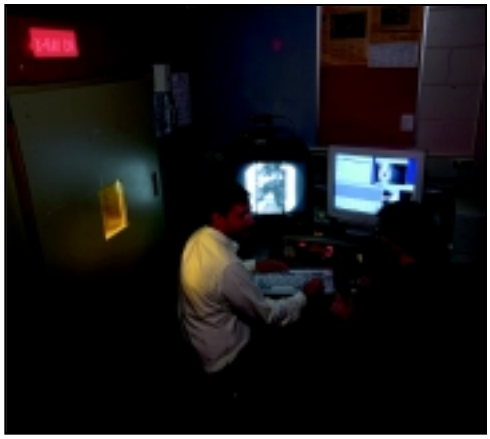
Currently, 32 program graduates are enrolled at ISU, and 25 are pursuing technical degrees in such areas as electrical engineering, computer engineering, pre-professional health, agriculture and biochemistry. This group has received a number of honors, from academic recognition to leadership positions. In 1999, a graduate was recognized for being in the top two percent in two colleges, and another was elected national president of a minority student agricultural organization.

CNDE: Building a bridge between ISU and community colleges through nondestructive evaluation

Enhancing education in nondestructive evaluation techniques for community college and university technical degree programs is the focus of the North Central Collaboration for Education in NDE/NDT. Funded by the National Science Foundation, the three-year program, nearing completion in the 1999-2000 academic year, is a consortium of four Midwestern two-year postsecondary institutions, Iowa State University and regional high schools.

Throughout the three years of the program, these institutions have worked collaboratively toward the following accomplishments:

- Hosted NDE Engineering Information Days at ISU, involving presentations by ISU faculty and NDE researchers, and facility tours.
- Completed professional development programs for community college instructors.
- Conducted 10-week summer internship programs to allow community college students to experience ISU engineering classes and NDE research.
- Awarded scholarships to a community college transfer student who ultimately completed an engineering degree at ISU.
- Worked with ISU's College of Engineering Student Services Office to establish routes for community college students to transfer to ISU.
- Developed materials to introduce NDE as a possible career choice to high school students.
- Is working to improve the quality of education that students receive in community college NDE programs. This effort includes adapting NDE simulation models developed at CNDE for use as community college teaching tools and developing interactive computer-based educational materials.



VRAC: Opening a window to enhance education

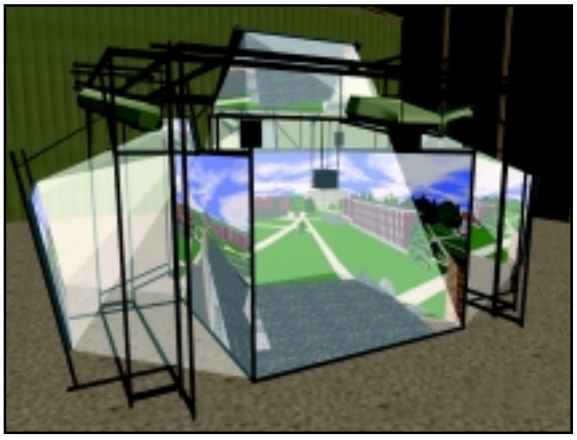
Enhancing education is a key tenet of advancing technology. But how do you allow students from more than 60 school districts across the state to take a field trip to one of the premier virtual reality facilities in the world?

The Iowa Communications Network took on that challenge in April 1999 when it facilitated a visit by students in grades 6-12 to the C2 VR environment. IPRT scientists conducted an educational tour using the interactive video conferencing ability of ICN.

A select group of students wore stereo glasses, creating a VR experience similar to that on-site. Students from 20 schools also interacted with IPRT researchers while the remaining schools listened in on the exchange.

C2 is a 12-by-12-by-9 ft. room that allows projection of 3-D images on three walls and the floor in real time to immerse the user in computer-generated surroundings. During the session, students toured "Cuevadefuego" (the fire cave), a factory and Speyer Cathedral in Germany. They also learned about virtual prototyping as they looked at a simulation of a farm tractor.

Responses from students and teachers were positive, according to Jenny Townsend, ICN distance learning coordinator. One teacher commented that it exposed her students "to new technology that we would not be able to see because of geographic location." Said another, "this activity opened a window for us!"



1999 News Briefs

Energy Secretary's visit

Industrial advisory board

Portable eddy-current scanner

For the first time, a cabinet-level official visited the Ames Laboratory. U.S. Department of Energy Secretary Bill Richardson visited the Lab in September and sampled research, including lead-free solder, magnetic refrigeration, cluster computing and thin-film technologies. "I am delighted to be the first Secretary of Energy to ever visit Ames Laboratory . . . this is an important facility that we want to continue and perhaps expand," Richardson commented.

IPRT has instituted a 10-member industrial advisory board to provide insight and to assist in organizational planning. The board includes top-level research and development officials from Fortune 500 and other major companies. According to Director Tom Barton, expertise from these industry leaders will have an "incalculable, positive impact on IPRT." The group met in early November at ISU to visit IPRT centers and to partake in presentations and discussions on IPRT's future direction.

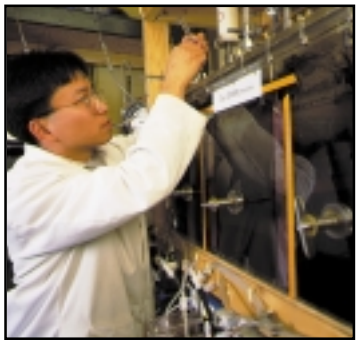
IPRT renewed support for the Research Seed-funding Program, an initiative that provides seed funds for interdisciplinary research designed to support Iowa economic development. In its second year, more than $260,000 was awarded to five projects, including new tissue engineering techniques for breast reconstructive surgery; design and construction of a system to prepare high-purity microminiature materials for industrial uses; synthesis of porous aluminum sieves for use in chemical reactions and technology development; new coating structures and analysis tools for orthopedic and dental implants and development of a regional forensics support and research facility.

The Center for Sustainable Environmental Technologies received two grants from the Department of Energy's University Coal Research Grant Program to improve hot gas clean-up in coal plants. The "core program" grants will support research in hot gas contaminant and particulate removal techniques, areas where improvement is needed because current practices limit a plant's efficiency. Research will be conducted by faculty in the departments of mechanical engineering, chemical engineering and materials science and engineering.

The Engine Titanium Consortium, an alliance of major industry partners and Iowa State University, developed a portable eddy-current scanner to detect imperfections in titanium, the material used to construct most aircraft engines. Scientists at the Center for Nondestructive Evaluation and other ETC members worked to create the device that enables fast, versatile inspection of engines. The eddy-current technology is able to detect near-surface defects with more sensitivity and reliability than existing detection methods.

The Center for Physical and Computational Mathematics has acquired a 768-processor supercomputer named the Paragon. The fastest computer in Iowa and among the top 300 fastest super computers in the world, the Paragon was acquired after being decommissioned by fellow DOE laboratory, Oak Ridge National Laboratory. Ames Laboratory researchers are currently using the Paragon to determine the melting point of materials whose temperatures are so high they cannot be duplicated in a laboratory setting and to simulate how electromagnetic waves travel through various media.

IPRT receives R&D 100 award



"The TPAD process is a giant step forward in the technology of wastewater sludge digestion. The process is simple, yet effective in generating a product that has many more uses and therefore more value."—Shihwu Sung, assistant professor, civil and construction engineering

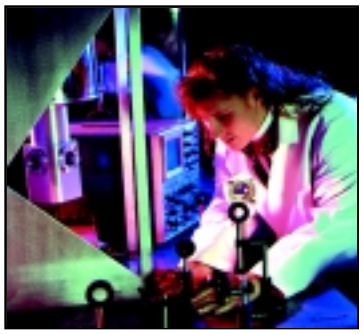
Richard Dague has posthumously received an R&D 100 award for a new sewage treatment process called Temperature-phased Anaerobic Digestion. The CATD-funded project is an improvement over conventional sewage treatment techniques because it converts sewage sludge into a Class A biosolid. Class A biosolids may be used as fertilizer, thus avoiding expensive disposal costs. TPAD removes 99.999 percent of the harmful pathogens in sewage sludge. In addition to producing a safer sludge, TPAD produces 15-20 percent more methane, which may be used as a replacement for liquid propane or natural gas. The process also produces less solid mass and odor than other treatment methods.

"The TPAD process is a giant step forward in the technology of wastewater sludge digestion. The process is simple, yet effective in generating a product that has many more uses and therefore more value," said Shihwu Sung. Sung, an assistant professor in civil and construction engineering, assisted Dague and private-sector researchers Sandra Kaiser and William Harris in developing the process.

Sung added that an existing plant can be modified to use the TPAD process for a small investment. "It is an excellent process that will improve the environment and also pay for itself in a short period," he said.

TPAD has been licensed by the ISU Research Foundation to Anaerobic Biosystems Corporation of Ames and is used in 12 wastewater treatment plants throughout the United States.

Advanced laboratory completed for optoelectronics experiments



IPRT scientists from diverse fields can conduct cutting-edge laser- and optics-based experiments in MRC's new Quantum-Spectroscopy Laboratory.

A new laboratory at ISU will make possible state-of-the-art laser- and optics-based experiments that may advance research into new and electrically and optically active materials and devices, such as lasers, transistors and novel quantum-field effect devices.

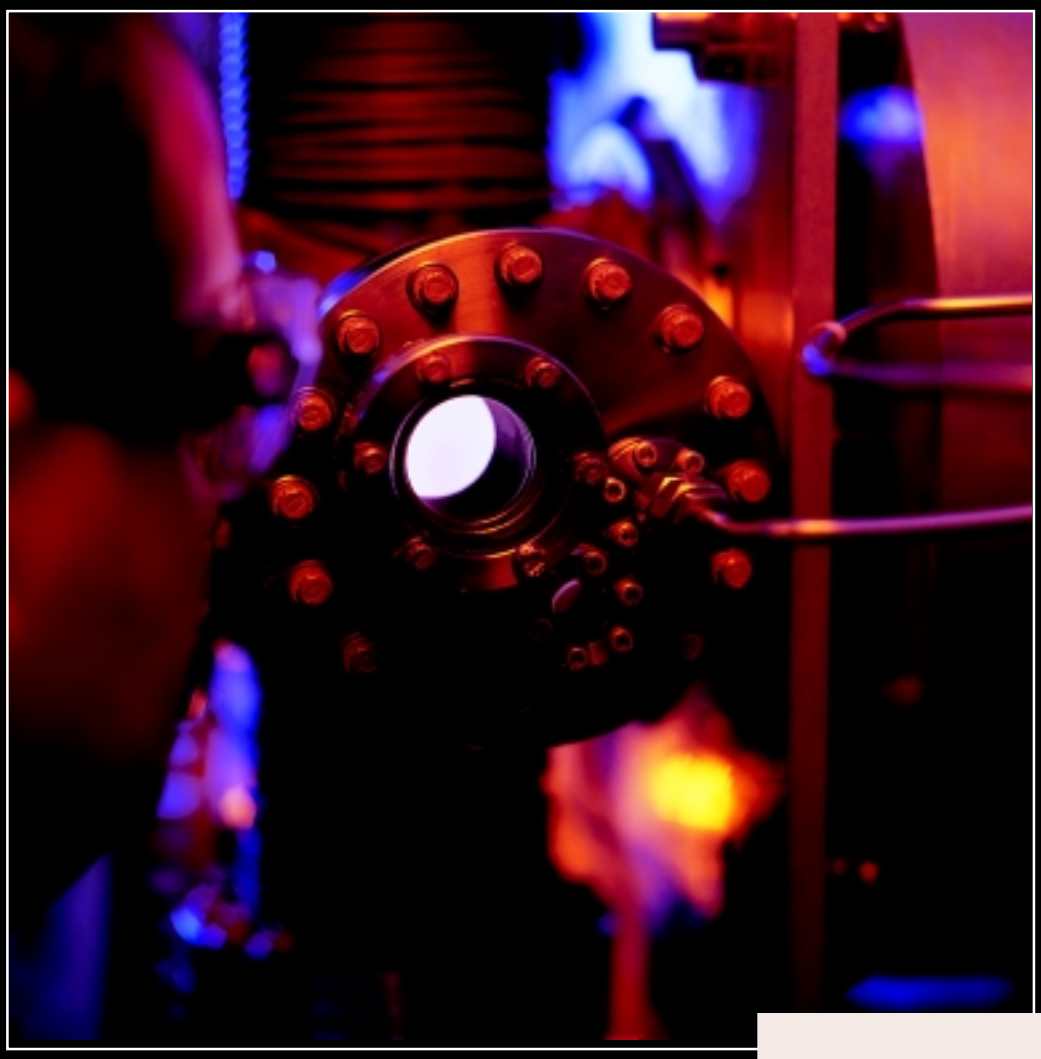
Located at ISU's Microelectronics Research Center, the Quantum-Spectroscopy Laboratory is equipped with unique instrumentation in six interdependent minilabs for basic research into electronic, optical, vibrational and fast-transient behavior of condensed matter systems.

The laboratory, which consists of high-tech equipment donated and purchased from IBM, is expected to play a key role in optoelectronic research important to the development of new microelectronic and bioelectronics systems. Researchers from disciplines as diverse as physics, chemistry, materials science, electrical engineering, chemical engineering and molecular biology will be able to carry out equally diverse optoelectronic experiments in the new facility.

Lab founder Don Wolford, a professor of physics, said, "Our new Quantum-Spectroscopy Lab is expected to prepare students and faculty to compete in the increasingly sophisticated and interdisciplinary worlds of 21st-century nanoelectronic and biological sciences and their technological applications."

The Future of IPRT:

2000 and Beyond



■ The Microelectronics Research Center's plasma-deposition reactor deposits thin films of electronic materials onto plastic substrates.

IPRT Centers are Actively Advancing Technology in 2000

Premier forum for immersive technologies to convene at ISU

The 4th International Immersive Projection Technology Workshop, called IPT 2000, will be held June 19-20 at ISU's Howe Hall. Organized by IPRT's Virtual Reality Applications Center and the Fraunhofer Institute Industrial Engineering, Stuttgart, Germany, the conference will showcase new and unique work in projection-based immersive environments for virtual reality applications. Teachers, students, artists, engineers, researchers and managers from around the world are expected to attend.

Meet IPRT at Technology Outreach 2000

IPRT and the ISU College of Engineering are cosponsoring Technology Outreach 2000, June 22-23 at Howe Hall. This event will provide Iowa technical leaders with an opportunity to learn how to access Iowa State's technologies and outreach services.

International summer school for NDE educators

The World Federation of NDE Centers is planning an international summer school at ISU from July 3-Aug. 4. Approximately four scientists from each of 14 NDE member centers in Argentina, Belarus, Brazil, China, India, Korea, Poland, Russia, South Africa, Taiwan and the Ukraine will join ISU scientists for the summer session.

The attendees will be university engineering and science faculty who hope to exchange knowledge on NDE education and training and initiate cooperative research efforts. "Our goal is to establish uniformity in NDE skills and technology across the world," said Satish Udpa, permanent secretary of the federation. "We hope to establish a uniform curricula for all NDE educators."

Attendees will participate in workshops and attend the Annual Review of Progress in Quantitative Nondestructive Evaluation.

World's foremost NDE research conference to be held at ISU in July 2000

The 27th Annual Review of Progress in Quantitative Nondestructive Evaluation will be held at ISU July 16-21. The review is organized by QNDE Programs and the Center for Nondestructive Evaluation at Iowa State University in cooperation with the American Society for Nondestructive Testing, the U.S. Department of Energy, the Federal Aviation Administration, NASA-Langley Research Center and the National Science Foundation (Industry/University Cooperative Research Centers).

QNDE is regarded as the world's foremost NDE research conference and fosters information transfer from advanced research programs to industry. Researchers from around the globe present nearly 400 technical papers each year, which are then collectively published in hard-bound conference proceedings.

Watch Us Grow!

Howe Hall

VRAC moves to Howe Hall

In October, the Virtual Reality Applications Center moved to Howe Hall, the first phase of the Engineering Teaching and Research Complex at ISU. The facility will also house VRAC's C6, a next-generation virtual reality room. VRAC's new neighbors include the department of aerospace engineering and engineering mechanics, engineering distance education, the Center for Industrial Research and Service, the Iowa Space Consortium and high-tech facilities for engineering instruction.

BECON opening

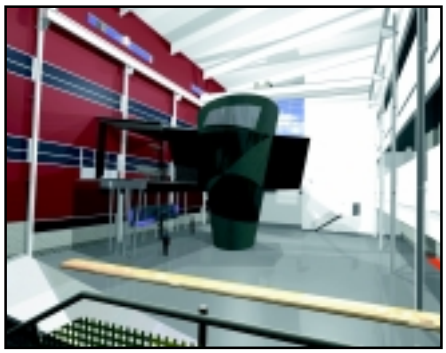
The Biomass Energy CONversion Facility in Nevada, Iowa, was unveiled to the public at a dedication ceremony in mid-November. BECON, an Iowa Energy Center facility, houses several IPRT research projects designed to convert biomass into environmentally viable fuels and chemicals.

Biomass Energy CONversion Facility

MIC's new facilities

The Microanalytical Instrumentation Center is growing with the addition of two new facilities. Nearing completion are the W.M. Keck Laboratory for the Fabrication of Microminiaturized Analytical Instrumentation in Gilman Hall and the Roy J. Carver Laboratory for Ultrahigh Resolution Biological Microscopy in the Molecular Biology Building. The Keck Laboratory will house microfabrication hardware in a 1,000 square-foot clean-room facility. The Carver Laboratory will have state-of-the-art microscopy instrumentation. These new facilities will enable ISU scientists to pursue a wide range of cross-disciplinary projects, from chemical laboratories on chips to cellular communication.

Carver Laboratory



C6 virtual reality environment

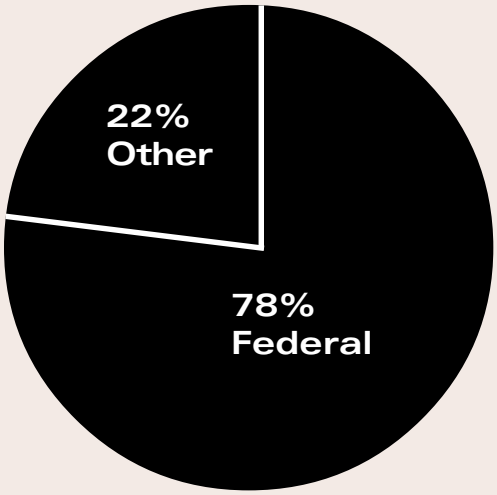
Introducing C6

An improved version of the Virtual Reality Applications Center's C2 three-dimensional synthetic environment is set to be installed in the atrium of ISU's Howe Hall in Summer 2000. C2 is a simulator that projects three-dimensional images on the front, side walls and floor of a 12-by-12-by-9 ft. room. The new C6 will project these images on all six walls of a larger room to completely immerse the user in a fully three-dimensional environment. C6 will run on two different platforms: a high-performance SGI system and a low-cost system to research cost-effective virtual reality environments. Additionally, C2 and C6 will be linked by fiber optic cable to study long-distance collaborative research. C6 is being built with assistance from the National Science Foundation, ISU and corporate sponsors.

IPRT Administrative Report

More than 760 faculty, professional, clerical and student employees serve IPRT. Over one-third of IPRT's staff is composed of graduate and undergraduate students who contribute to IPRT's excellence while seeking degrees.

In fiscal year 1998-99, IPRT programs and projects received funding totaling $45.7 million. Federal agency grants composed 78% of this funding, with U.S. Department of Energy's support for ISU's management and operation of the Ames Laboratory accounting for more than half of that amount. State of Iowa special appropriations for economic development, industrial contracts, ISU allocations, memberships and gifts provided the remaining 22%.



Interactions

FY 1998–99

Each year, a number of academic, public and corporate institutions contact IPRT for assistance. That assistance may result in an interaction ranging from a referral to a full research project. This list is incomplete, as many companies request confidentiality.

Iowa

8VA Corp

AATI
AERO Race Wheels
AFECO
AG Parts
Ajinomoto USA
Alliant Power
Aluminum Co. of America
Amana
American Athletic
Ampel Corp.
Anamosa High School
AP/M Permaform
Archer Daniels Midland
Army Aviation Support Facility

Ballistic Automotive Design
BJ Pipeline Cleaners
Bluewave Ultrasonics
BMD Co.
Bobalee Hydraulics
Bonser's Pasta Products

Candleworks
Cannon Technologies
Carbon Energy Technology
Cargill
Cedar Rapids Water Pollution Control
Centro Inc.
Chariton Valley Research, Conservation & Dev.
Check-All Valve
City of Ames
Clearline Cutlery Mfg.
Composites Technologies
Compressor Controls
Curries Co.

DeKalb Genetics Corp.
Delavan Inc.
Delta-Tie
Des Moines Water Works
Diablo Products
Diamond V Mills
Diamond Animal Health
Drake University

Eaton Corp.
Edge Technologies
Electro-Coatings
Elite Visions
Engineering Animation
EquiStar Chemicals
ETREMA Products

Fairfield Aluminum Castings Co.
FarmChem Corp.
Fisher Controls
Freiburger Waste Services
Frigidaire Home Products
Frog Legs Inc.
Frontier Laboratory

Golden Circle Air
Grain Processing Corp.
Grand Prix Power

H&H Trailers
Hach
Hammer's Plastic Recycling
HON Industries
Horizon Technology
Hy-Line International
Hydraulic Technologies

IMI Cornelius
Impro Products
Indian Hills Community College
Industrial Laminates/Norplex
Innovative Lighting
Iowa Air National Guard
Iowa Army National Guard
Iowa Dept. of Agriculture & Land Stewardship
Iowa Dept. of Natural Resources
Iowa Energy Center
Iowa Mold Tooling
Iowa Soybean Promotion Board
Iowa State Criminalistics Laboratory
Iowa Thin Film Technologies

Jacobs Corp.
John Deere, Des Moines Works
John Deere, Ottumwa Works
John Deere, Waterloo Works
Johnson Manufacturing

Katecho Inc.
Ken Way Manufacturing
Kinzler Construction Services
Kloubec Fish Farms

Land O' Lakes
Lee Ltd.
LGI
Litton Life Support

Marshalltown Trowel
Maytag Corp.
McKee Button
MechDyne Corp.
Medical Industries of America
Mercury Plastics Engineering Inc.
Merrill Manufacturing
Metal Technologies
Metalcraft
Michael Couch Inc.
Millard Refrigerated Services
Monarch Manufacturing
Monsanto Co.
Montezuma Manufacturing
Moulded Fibre Technology
MSI Mold Builders

National Starch & Chemical Corp.
Nelson Mfg.
Nevada Metalworks
Nichols Aluminum
Nolin Milling
Norplex Oak
Novartis

Original Saw Co.

Panel Components
PCT Engineered Systems
PeopleService
Pioneer Hi-Bred International
PMX Industries
Positech
Powell Consultants
Prairie Land Bio-Products
Prince Manufacturing

Rockwell Collins
Ron Holland House Moving
Roto-Rooter Corp.
Ryko Manufacturing
Saber Communication Corp.
Sauer-Sundstrand
Schebler
Science Center of Iowa
Scranton Manufacturing
Shakespeare-Fore Clothing
Shivvers
Silicon Graphics Inc.
Snap-on Tools
Square D
Steger Heiderscheit Construction

Tanks-a-Lot
Technology Labs

The PH Factor
Transco Railway Products
Tri/Mark
Tri-State Grain Conditioning

Unibox
University of Iowa
US Mfg.

V-T Industries
VayTek
Vermeer Manufacturing
VGK Inc.
Victor Plastics Inc.

Warren Packaging Corp.
Webster City Custom Meats
Williamsburg Manufacturing
Winegard
Winnebago Industries
Wold Rim & Wheel Service

United States

3M Corp.
AANC
Ablation Technologies
Advanced Forming Technology
Aeroquip Corp.
Aerotech Engineering & Research
Aging Aircraft Nondestructive Inspection Validation Center
Air Products & Chemicals
Air Transport Assoc.
Aircraft Belts
Aircraft Braking Systems
Alliant Energy
Alliant TechSystems
AlliedSignal
AlliedSignal Aerospace-Aircraft Landing Systems
AlliedSignal Propulsion Engines
Allison Engine
Alteon
Alumax Engineered Metal Products
Aluminum Co. of America (Alcoa)
America West Airlines
American Airlines
American Superconductor
Amoco
APL Engineered Materials
Applegate Group
Archer Daniels Midland
ARCO
ARCO/AEPT
Argonne National Laboratory
ARINC
Arizona State University
Arnold Engineering
Arris International
Association of American Railroads
Astronautics Corp. of America
Atlantic Metals & Alloys Inc.
Atomergic Chemetals
Autoliv
Automated Analysis
Aviation Safety Systems Development & Validation Center
Aviation Data Service

B/E Aerospace
Bell Laboratories
Bergstrom Inc.
BF Goodrich
Bodycote IMT
Boeing Commercial Airplane
BOSE
Bradley University
Brookhaven National Laboratory
Brown University

C.S. Draper Laboratory
Cargill
Carnegie Mellon Research Institute
Carnegie Mellon University
Cessna
Caterpillar
CERAC
CETAC Technologies
Chevron Research & Technology
Chrysler
Clark Atlanta University
Clark College
Clemson University
Cleveland State University
Colorado State University
Columbia University
Columbus S.M. LLC
Compaq
Continental Airlines
Cornell University
Council of Great Lakes Governors (Great Lakes Regional Biomass Energy Program)
Cretex
Crucible Research
Crumax Magnetics
CTI
Cummins Engine
Cytec-Fiberite

Deere & Co.
Delphi Inc.
Delta Airlines
Dexter Magnetic Materials
Dexter Magnetic Technologies
Dico
Digirad
Dionex
Dow AgroSciences
Drexel University
DuPont
Duracell Inc.

E-Systems
Eaton
Edge Consulting Group
Edge Technologies
Edison Welding
Electric Power Research Institute (EPRI)
Elemental Scientific
Embry-Riddle Aeronautical University
ENECO
Energen
Engelhard
Engineered Coating
Engineering Research
Eppley Institute of Cancer Research
Ervin Product Development Center

F.G. Jones Associates
Federal Aviation Administration
Federal Railway Administration
Ferro Electronic Materials
FETC
First Technology Safety Systems
Ford Motor Co.
Ford Research Laboratory
Foster Wheeler
Foundry Networks
Framatome

Gateway 2000
GE Lighting
General Atomics
General Electric
General Electric Aircraft Engines
General Electric Corporate R&D Center
General Motors
General Motors Research & Development
George Mason University
Georgia Institute of Technology
Georgia Tech
GEOTREX
GFS Chemicals
GM-Delphi
GNB Technologies

H.C. Stark
Hamilton Standard
Haynes International
Herzog Services
Hewlett-Packard
Hi-Z Technology
Hicks Dome
Hitachi Magnetics
HJD Intl.
Hoechst Celanese
Hon
Howmet

IBADEX
IBM
Idaho National Engineering Laboratory
IGC Advanced Superconductors
Impact Dynamics Inc.
Indiana University
Inspection Technologies Inc.
International Specialty Alloys
Isonics

J.I. Case
Jentek Sensors
Jet Propulsion Laboratory
Johns Hopkins University
Johnson Matthey Electronics

Kansas Technology Enterprise
KBS2 Inc.
Kent State University
Keystone Railway Equipment
Knolls Atomic Power Laboratory
Krautkramer Branson
Kulicke & Soffa Industries

Ladish Co.
Lawrence Livermore National Laboratory
LeTourneau University
Lincoln Composites
Livermore Software Technology
Lockheed Martin
Lockheed Martin Corp. Aeronautics Materials Mgmt Ctr.
Lockheed Martin Energy Research
Lockheed Martin Energy Systems
Lone Peak Engineering
Lone Star Steel
Los Alamos National Laboratory
Lucent Technologies
Lynntech

Magnequench Intl. Inc.
Maintenance Concepts
Marlow Industries
Massachusetts Institute of Technology
Material Technology
Materials & Electrochemical Research
Maui High-Performance Computing Center
Metal Mining Agency of Japan
Metal Powder Industries Federation
MGA Research
Michigan State
Micrion
Micro-Cut Engineering
Midwest Express
Mississippi State University
Mitsui & Co. (USA)
Molecular Structure Corp.
Monsanto
Morton International

NASA-Langley Research Center
NASA Lewis
National Institutes of Health
National Institute of Standards & Technology
National Center for Supercomputing Applications
National Renewable Energy Laboratory
National Science Foundation
National Starch & Chemical
National Transportation Safety Board
Naval Surface Warfare Center
Navistar
Navy Postgraduate School
Navy Research Laboratory
NEC Research Institute
NEOCO, L.C.
Nicolet Technical Symposium
Noah Technologies
Nondestructive Testing Information Analysis Center
Nonvolatile Electronics
North Carolina State University
Northeastern University
Northern States Power
Northrop Grumman Aerospace
Northrop Grumman Commercial Aircraft Division
Northwest Airlines
Northwestern University
Notre Dame
NSF/Stevens Institute
Numerical Integrations Inc.

Oak Ridge National Laboratory
Ohio State University
Oklahoma State University
Orbit Industries
Oremet
Orlando Technology Inc.
Orthopaedic Research Institute
OSRAM Sylvania Inc.
Ovonic Battery
Oxford Superconducting Technology

Pacific Industrial Development
Pacific Northwest National Laboratory
Pacific Scientific
Packet Engines
Palm Commodities International
Parker Hannifin
Pennsylvania State University
Performance Alloys & Materials Inc.
Phillips Petroleum
Physical Research Inc.
Plastic Specialties
Practical Imagineering
Pratt & Whitney
Praxair Surface Technologies
Princeton Electro-Technology
ProChem Inc.
Procter & Gamble
ProdiGene
Protein Technologies International
Purdue University
Pyramid Systems

Quality Link Resources
Queens College

R/D Tech
Raytheon Aircraft
Reality Centre Solutions Architect
REB Research & Consulting
Reflective Energies
Rensselaer Institute
Rhodia
RMI Inc.
Rockwell Automation
Rolls Royce Allison

San Diego State University
Sandia National Laboratories
Sausville Chemical Co.
Savannah River Research Center
Schlumberger Austin Research
Schlumberger-Doll Research
Science Applications International
Seagate Technology
Sense8
SEOS Displays Ltd.
Shell Oil Company
Siemens Westinghouse
Sierra Matrix
Silicon Graphics Inc.
Sinko Resources
SMPC Specialty Metals Processing Consortium
Sonix
Sophisticated Alloys
Southwest Airlines
Southwest Research Institute
Specialty Metals
Sperry Rail Service
Spitz Inc.
SQM Technology
SRI International
Stanford
Stanford Materials
State University of New York
Strategic Sciences
Structural Integrity Associates
Sumitomo Special Metals America
Sun Microsystems
Supercon
Symyx Technologies
Synterials
Syracuse University
Syskonnect Inc.

Talley Defense Systems
TASC
Technic Inc.
Technics Inc. Engineered Powders
Technology Assessment & Transfer
TELAC
Teledyne-Allvac
Texas A&M University
Tianjiao International Inc.
Timet
Titanium Hearth Technologies
Tomen America Inc.
Transom Technologies
TransWorld Airlines
Treibacher USA
Tridus International
Truman State University
TRW
Tuskegee University

U. S. Department of Agriculture
U. S. Department of Defense
U. S. DOE Office of Industrial Technologies
Ugimag
United Airlines
United States Air Force-Kelly AFB
United States Air Force-McClellan AFB
United States Air Force-Robins AFB
United States Air Force-Tinker AFB
United States Air Force-Wright Patterson
United States Army Picatinny Arsenal
United States Coast Guard
United Technologies Research Center
University of Arizona
University of Buffalo-SUNY
University of California
University of California-Davis
University of California-Irvine
University of California-San Diego
University of Cincinnati
University of Connecticut
University of Dayton Research Institute
University of Florida
University of Houston
University of Illinois
University of Illinois-Chicago
University of Kansas
University of Maryland
University of Michigan
University of Minnesota
University of Missouri
University of Nebraska
University of Nebraska-Lincoln
University of North Carolina
University of North Carolina-Chapel Hill
University of North Dakota
University of Oklahoma
University of Oregon
University of Pennsylvania
University of Texas
University of Texas-Dallas
University of Utah
University of Virginia
University of Washington
University of Wisconsin
University of Wyoming
UniWest
US Air
US Air Express
USAF 45th Space Wing
USGS/EROS Data Center
USR Optonix
Utah State Valley College

Vanderbilt University
VisionAire
VRCO

W.R. Grace
Walker Magnetics Group
Walt Disney Imagineering
Warren Diamond Powder
Washington University
Wayne State University
Webster Hoff
West Penn Testing Laboratories
Western Washington University
Westinghouse Electric
Westinghouse Savannah River
Williams Intl.
Wheeler Associates
Wichita State University
Wyman Gordon

Xactex
Xylan

International

Argentina
Ciudad Universitaria

Australia
Ashton Mining Ltd.
Australian National University
CSIRO
Griffiths University
La Trobe University
Prima Resources
University of Melbourne
University of Queensland

Austria
Technische University
Treibacher Auermet Produktionsges
University of Innsbruck

Belgium
NATO
R.E.M. s.a.

Brazil
Industrias Nucleares do Brasil
Instituto d Engerharia Nuclear

Canada
AMR Technologies, Inc.
ANDEC Mfg. Ltd.
Carleton University
Electrohome Ltd.
Integrated Manufacturing Technologies
Iona Appliances
Logical Vision Ltd.
National Defence HQ
Ontario Hydro
Pratt & Whitney
Resource Transforms International
Silicon Graphics Canada
Syncrude Canada
Tektrend Corp.
Transport Canada
University of British Columbia
University of Québec
University of Victoria
University of Waterloo
University of Western Ontario

El Salvador
Manufacturas Humberto Bukele E Hijos
Sintesis

Finland
Helsinki University of Technology

France
Aerospatiale
Alcatel
CEZUS
Electricité de France
ESRF-Grenoble
NDT Systems S.A.
Rhodia Terres Rares
Saint-Gobain
SNECMA
University of Aix-Marseille III
University of Bordeaux
University of Caen
University of Compiegne
University of Lille
University of Montpelliar
University of Paris
University of Poincare

Germany
Auer-Remy GmbH
Bundesanstalt für Materialforschung
Fraunhofer IAO
Fraunhofer IGD
GMD German National Research Center
High Performance Computing Center
Karl Deutsch
Mainz University
Max-Planck-Institut fur Chemie
MBB
Silicon Graphics
Universitat Augsburg
Universitat Muenster
Universitaet Karlsruhe
University of Kassel
University of Stuttgart
Vacuumschmelze GmbH

Hong Kong
Future Industrial Ltd.
ONFEM Holdings Ltd.

Hungary
Central Research Institute for Physics

India
Indian Institute of Technology
Indian Rare Earths Ltd.
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